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HUMANS' SENSITIVITY TO VARIATION IN REINFORCER AMOUNT: EFFECTS OF THE METHOD OF REINFORCER DELIVERY

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Two experiments examined human subjects' sensitivity to variation in reinforcer amount under different methods of reinforcer delivery. Subjects chose between schedules varying in terms of amount and/or delay of reinforcement, the reinforcer being points exchangeable for money. In Experiment 1, reinforcer amount was manipulated by varying the monetary value of the points across conditions while the number of seconds of access to a consummatory response remained constant. Choice was strongly sensitive to reinforcer amount and indicative of self-control, as in previous experiments. In Experiment 2, reinforcer amount was manipulated by automatically delivering different numbers of points during the amount period, and the consummatory response was eliminated. Sensitivity to variation in reinforcer amount was significantly lower than in Experiment 1. Furthermore, the subjects in Experiment 2 exhibited significantly less self-control than did the subjects in Experiment 1. Humans' sensitivity to variation in reinforcer amount appears to be affected by factors that enhance the discriminability of the consequences of responding.

Key words: amount of reinforcement, delay of reinforcement, consummatory response, schedule sensitivity, self-control, rod push, humans

A critical issue in operant research, including research with human subjects, is the degree to which particular results are specific to an experimental paradigm or set of procedures as opposed to being generalizable to other domains. In other words, how do environmental factors other than the schedule of reinforcement affect behavior?

One group of experiments examining the effects of environmental variables involves the effects on responding of the way in which the reinforcer is obtained (Hawkins & Pliskoff, 1964; Iglauer & Woods, 1974; Llewellyn, Iglauer, & Woods, 1976). For example, Hawkins and Pliskoff found that rats were insensitive to the schedule contingencies unless the reinforcer (electrical brain stimulation) was produced by a separate consummatory response in the terminal link of a chain schedule (similar to the types of behavior involved in ingesting a food reinforcer).

Experiments with humans have produced similar results under some conditions. In these experiments the reinforcer typically has been points exchangeable for money (Buskist & Miller, 1982). The results of such studies indicate that the degree to which human subjects' behavior varies according to the contingencies of reinforcement is often a function of the particular experimental setting (Holland, 1958; Long, Hammack, May, & Campbell, 1958; Matthews, Shimoff, Catania, & Sagvolden, 1977; McDowell & Wood, 1984, 1985; Shimoff, Catania, & Matthews, 1981). For example, Matthews et al. (1977) examined human subjects' responding on variable-ratio (VR) and on yoked variable-interval (VI) schedules. All subjects were required to push a telegraph key (the operant response) in order to earn the reinforcer (points exchangeable for money). Some subjects were also required to perform a second, consummatory response to earn points. Similar to the results of Hawkins and Pliskoff (1964), the results indicated that if a consummatory response were present, the subjects responded at a higher rate on the VR schedule. However, if the consummatory response were not present, the subjects responded at similar rates on the yoked VI and VR schedules. These conclusions are supported by the findings of Wurster and Griffiths (1979). In their experiment human subjects were exposed to concurrent VI VI schedules. Amount of reinforcers was varied by automatically delivering different numbers of points during the reinforcement periods (i.e., there

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was no consummatory response). The subjects' responding did not change as a function of reinforcer magnitude.

In contrast to the above experiments, Buskist, Oliveira-Castro, and Bennett (1988) obtained changes in human subjects' behavior according to the schedule of reinforcement even with no consummatory response. Their subjects were exposed to various fixed-interval (FI) schedules of reinforcement in which reinforcer magnitude was correlated with response rate. Under these conditions the subjects increased their response rates. McDowell and Wood (1984) found similar results. In their experiment, the effects of amount of reinforcement were examined by varying the monetary value of each point across conditions. Response rate on a single manipulandum increased with reinforcer magnitude. Together, these results indicate that, at least within some experimental paradigms, human subjects' behavior does vary according to the reinforcement contingencies even when a consummatory response is absent. However, the basis for the differing results across all of the studies that manipulated reinforcer amount is not known.

One choice situation that involves the manipulation of reinforcer amount is the self-control paradigm. Self-control can be defined as the choice of a larger, more delayed reinforcer over a smaller, less delayed reinforcer. Impulsiveness is the opposite of self-control, that is, the choice of a smaller, less delayed reinforcer over a larger, more delayed reinforcer (Ainslie, 1974; Grosch & Neuringer, 1981; Rachlin, 1974; Rachlin & Green, 1972). Therefore, the two critical determinants of self-control and impulsiveness are sensitivity to variations in reinforcer amount and sensitivity to variations in reinforcer delay (Navarick, 1988).

The effects of different methods of delivering reinforcer amount have not been assessed within a self-control paradigm, which by definition involves the manipulation of reinforcer amount and delay. In this paradigm the typical method of varying reinforcer amount (with points as the reinforcer) has been to vary the number of seconds of access to a consummatory response while the monetary value of the points remains constant (e.g., King & Logue, 1987; Logue, Peña-Correal, Rodriguez, & Kabela, 1986). Using this procedure to manipulate reinforcer amount, human subjects are very sensitive to variations in reinforcer amount relative to variations in reinforcer delay and tend to demonstrate self-control under a variety of different procedural manipulations (e.g., King & Logue, 1987; Logue et al., 1986).

However, with this procedure the obtained amount of reinforcers depends on how many times the subject performs the consummatory response (i.e., how quickly the subject turns a knob) during the reinforcer access period. The subjects may not operate the consummatory response at a constant rate during the access periods. For example, subjects may operate the consummatory response at a slower rate during longer access periods than during shorter access periods because they have a longer time to obtain points. Therefore, with this procedure, obtained reinforcer amount is not under direct experimental control and is not a completely independent variable.

Clearly, in a self-control paradigm as well as in other procedures, it would be preferable to eliminate the consummatory response altogether and to deliver different numbers of points to vary reinforcer amount, thereby obtaining greater experimental control over the contingencies of reinforcement. However, some of the above research indicates that human subjects may not be sensitive to the experimental contingencies when a consummatory response is absent. If insensitivity to the experimental contingencies in the absence of a consummatory response were obtained in a self-control paradigm, then elimination of the consummatory response would not be recommended for future research involving humans. Therefore, the effects of different methods of delivering reinforcer amount must be investigated to determine more precise procedures for future investigations involving variations of reinforcer amount, including investigations of self-control.

The following two experiments examined the effects of two different methods of delivering reinforcer amount on human subjects' sensitivity to variation in reinforcer amount and on self-control. Experiment 1 examined the effects of manipulating the monetary value of the points while the number of seconds of access to a consummatory response remained constant. Experiment 2 examined the effects of automatically delivering different numbers of points during the reinforcer period with no consummatory response present.

METHOD

Subjects

The subjects in each experiment were 6 experimentally naive adult undergraduate females between 18 and 23 years of age, all enrolled at the State University of New York at Stony Brook. They were recruited by posters placed around campus and advertisements placed in the university newspaper. No subject was a psychology major. All subjects were paid for their participation. The subjects in Experiment 1 were numbered 1 through 6 and those in Experiment 2 were numbered 7 through 12.

Apparatus

The experiments were conducted in a small room, 3.7 m by 1.9 m, that could be illuminated by a fluorescent light. One wall of the room contained a one-way mirror that allowed observation of the subject. The room contained a chair and a desk. The experimental apparatus was placed on the desk, which was located against one wall. The apparatus was a wooden box, 122 cm wide, 66 cm deep, and 81 cm high. The front of the apparatus was painted black.

An aluminum panel (see Figure 1), 35 cm wide and 51 cm high, on the front of the apparatus, contained the experimental stimuli and the manipulandum, an aluminum rod. The rod, 1.6 cm in diameter, protruded 14 cm from the panel and was mounted 4 cm from the bottom of the apparatus and equidistant from the sides. The rod could be pushed to the left or the right and required a minimum force of 18.8 N to operate in either direction. One translucent Plexiglas disk, 3.8 cm in diameter, was located on each side of the rod. The left disk could be transilluminated green, and the right disk red. A counter was located 11.8 cm above each Plexiglas disk. A knob, 2.5 cm in diameter, was located 5 cm above the rod. During Experiment 1, knob twists were effective only when a light, located 4 cm above the knob, was lit and a 1000-Hz tone was present. During Experiment 2, the knob was covered and ineffective. On the top front edge of the apparatus were three DBDS11 7.5-W light bulbs. The left light was green, the center light white, and the right light red. Located behind the three lights was a loudspeaker that emitted continuous white noise to mask extraneous sounds.

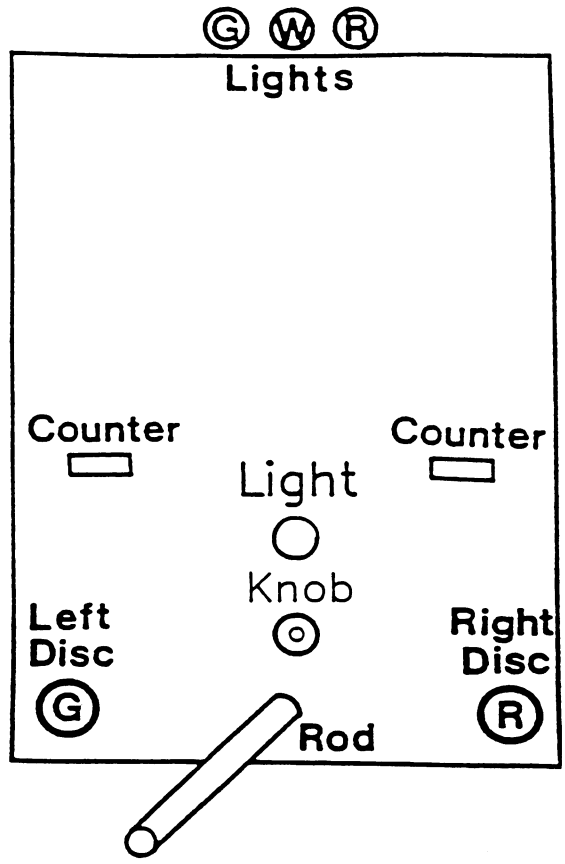

Fig. 1. Diagram of the aluminum panel used in the present experiments. The letters G, W, and R indicate the colors green, white, and red, respectively.

An IBM-XT® computer, located in another room, controlled the experimental stimuli and recorded responses using a CONMAN® program (CONMAN is similar to SUPERSKED®).

Procedure

General. Before each session, subjects were escorted into the experimental chamber. They were given the following minimal instructions as to what they were to do during the session (slightly modified for Experiment 2; see below):

> Please read carefully. Do not ask for additional instructions. Your task is to earn as many points as you can. The value of each point is displayed on the card above the counter. For example, if points are worth .10 cents and you

earn, 1,000 points, you will be paid $1.00. You may touch anything on this panel to earn points. The session will begin when one or more lights come on, and will end when all the lights turn off. To minimize interference with the equipment, please leave all metal objects (watches, jewelry, etc.) with the experimenter for the duration of the session. All other personal property (coats, books, writing utensils, pocketbooks, etc.) should also be left with the experimenter. These materials will be returned promptly at the session's end.

Instructions were kept to a minimum because previous research has shown that, under certain conditions, with minimal instructions humans may show more sensitivity to the scheduled contingencies (e.g., Matthews et al., 1977; Shimoff et al., 1981). The subjects were not told how to operate the operant panel, nor was their behavior shaped by the experimenter. Subjects were instructed to leave their watches and jewelry outside of the chamber to ensure that no subject had access to a timing device during the session. The use of timing devices in experiments can yield valuable data (Lowe, 1979). However, conditions in the present experiment were kept as similar as possible to those used with pigeons to help identify the origins of any differences between the behavior of human and nonhuman subjects. The experimenter then left the room, closed the door, and turned off the overhead light. There was no further communication between the subject and the experimenter until the end of the session.

At the beginning of a session, the left disk was green, the right disk was red, and the white light on the top of the apparatus was lit. When a reinforcer was received for a rod push to the left, both disks and the white houselight were darkened, and the left green light on top of the apparatus was turned on. A reinforcement period began with the programmed delay of reinforcement, followed by the programmed period of access to the reinforcer (the amount of reinforcement). During the reinforcer access period the green light remained on, the white light above the knob was lit, and a 1,000-Hz tone came on. After the reinforcer access period, both disks and the white light on top of the console were again lit. The sequence of events for reinforcement following a rod push to the right were similar to those for reinforcement following a rod push to the left except that the right red light on top of the apparatus was lit instead of the left green light. Rod pushes to the left or right were followed by a brief feedback click when the disks were lit; rod pushes when the disks were darkened had no effect and were not recorded. The cumulative number of points earned during left access periods was displayed on the left counter; those earned during right reinforcer access periods were displayed on the right counter.

Reinforcers were available according to modified concurrent independent VI 30-s VI 30-s schedules. The intervals for each schedule were constructed according to the method described by Fleshler and Hoffman (1962). The programming of the VI schedules was identical to that used by Logue, Rodriguez, Peña-Correal, and Mauro (1984, Experiment 2) with pigeons and by Logue et al. (1986, Experiments 2 through 5) and King and Logue (1987) with humans, and was similar to the linear VI schedules used by Vaughan (1982) that generate response rates similar to traditional VI schedules (see discussion by Prelec, 1983). Each VI schedule timed continuously during a session. Each time an interval in one of the VI schedules timed out, the schedule continued but a counter representing the number of available reinforcers was incremented. Each time a reinforcer was received the appropriate counter was decremented. This type of programming of concurrent schedules tends to keep the overall reinforcer frequency for the two alternatives more similar (although no necessarily equal) than does the traditional programming of concurrent schedules (see Logue et al., 1984, Experiment 2). A rod push toward a lit disk was followed by the reinforcer delay and reinforcer amount period if the counter for that VI schedule had a value of at least one and if the changeover delay (COD) requirement had been fulfilled. The COD specified the minimum period of time that had to elapse after a changeover from the last response on one alternative to the first response on the other alternative, or after the first response following reinforcement. A 3-s COD was in effect.

At the end of each session each subject completed a questionnaire asking how she thought the button became available and what she thought she did during the experiment. Subjects received $1.25 for the session. At the end

Table 1

Order of conditions for Experiments 1 and 2. The amounts (A_l and A_r) for Experiment 1 are the cents per point, and for Experiment 2 are the number of points arranged per reinforcement. The delays (D_l and D_r) are in seconds.

	Experiment 1		
	Subject 1	All other subjects	Experiment 2
Condition	A_l, A_r, D_l, D_r	A_l, A_r, D_l, D_r	A_l, A_r, D_l, D_r
1	0.17, 0.17, 6, 6	0.10, 0.10, 6, 6	22, 22, 6, 6
2	0.33, 0.11, 6, 6	0.21, 0.07, 6, 6	33, 11, 6, 6
3	0.17, 0.17, 10, 2	0.10, 0.10, 10, 2	22, 22, 10, 2
4	0.11, 0.33, 6, 6	0.07, 0.21, 6, 6	11, 33, 6, 6
5	0.17, 0.17, 2, 10	0.10, 0.10, 2, 10	22, 22, 2, 10
6	0.33, 0.11, 13, 0.2	0.21, 0.07, 13, 0.2	33, 11, 13, 0.2
7	0.11, 0.33, 0.2, 13	0.07, 0.21, 0.2, 13	11, 33, 0.2, 13

of the entire experiment, subjects also received the money that they had earned during the sessions.

The first session was a 30-min training session during which subjects learned to operate the apparatus. The contingencies for this training session were the same as for the first experimental session (see below), but the data from the training session were not used in any analyses. Each of the subsequent experimental sessions was 2 hr in duration. At the end of the first hour, the subject left the experimental chamber and took a 10-min break. After the break, the subject reentered the chamber for the remaining hour of the session. Data were collected in half-hour blocks, which were then used for later analyses. Subjects were exposed to each condition for one session for a total of seven 2-hr sessions per subject. Human behavior stabilizes quickly, and this method of data collection results in stable, consistent behavior in human subjects (e.g., see McDowell & Wood, 1984, 1985).

Table 1 presents the conditions to which each subject was exposed. The amounts (A_l) presented in Table 1 for Experiment 1 are in cents, but the amounts for Experiment 2 are the number of points arranged per reinforcer. The delays (D_l) for both experiments are in seconds. In the first condition the two amounts were the same (i.e., $A_l = A_r$ in Table 1), as were the delays (i.e., $D_l = D_r$ in Table 1). During the next four conditions, the amounts (Conditions 2 and 4) and delays (Conditions 3 and 5) were varied separately. Condition 4 was a reversal of Condition 2, and Condition 5 was a reversal of Condition 3. These reversals were designed to control for any position bias that may have been present. The final two conditions (Conditions 6 and 7) were self-control conditions in which the amounts and delays were varied together.

Experiment 1. In addition to the general procedure discussed above, during reinforcer access periods following a left rod push (when the white light above the knob was lit and the 1000-Hz tone was on), the knob was enabled: Each 90° turn of the knob, in either direction, added one point to the left counter. During reinforcer periods following a right rod push, events were similar except that the right counter was incremented. The counters displayed the cumulative number of points earned for each response alternative. The monetary value of each point for a given condition was displayed on a card (3 in. by 5 in.) mounted above the appropriate (left or right) counter. The absolute values of the points were decreased after Subject 1's sessions because of the large amount of money that this subject earned for the entire experiment ($160.00). However, the relative values of the points were the same for Subject 1 and the remaining 5 subjects. The reinforcer access period (the number of seconds the knob was available for each reinforcer) was always 6 s for both alternatives.

Experiment 2. As in Experiment 1, during the reinforcer access period the white light above the knob was lit and the 1000-Hz tone was on. Unlike Experiment 1, however, points were automatically delivered to the appropriate counter (i.e., the subject was not required to turn the knob to earn points). The fourth sentence of the instructions to the subjects was

changed to "Points are worth .10 cents," and the fifth sentence was changed to "Therefore, if you earn 1,000 points you will be paid $1.00." The value of each point and the number of points delivered per reinforcer were selected to ensure that the subjects in both experiments were exposed to similar conditions of reinforcement. This goal was accomplished by means of the following specific procedures: (a) the value of each point in Experiment 2 was equated with the baseline value used for 5 of the 6 subjects in Experiment 1 ($0.001); (b) the number of points per reinforcement in Experiment 2 was equated with the results of Experiment 1 (22 points per reinforcement in conditions with equal amounts); (c) the same programmed amount ratios were used in both experiments; and (d) the total amount earned by each subject was approximately equal for the two experiments. The duration of the point delivery period was 6.6 s for all conditions, and the rate of point delivery during reinforcer access periods varied across conditions.

RESULTS

General

All subjects learned to operate the panel efficiently during the 30-min training session without any instructions from or shaping by the experimenter. In Experiment 1 the mean amount earned during the training session was $1.23 ($SE$ = 0.22), and the mean number of obtained reinforcers was 58.17 (SE = 13.31); in Experiment 2 the mean amount earned during the training session was $1.62 ($SE$ = 0.20), and the mean number of obtained reinforcers was 74.17 (SE = 8.20).

Table 2 presents for each subject and each condition the number of left and right responses and the number of reinforcers received for left and right responses. In addition, for Experiment 1, the number of cents earned for each of these reinforcers, and for Experiment 2, the number of points delivered per reinforcer are presented. All of these data are means calculated over the four half-hour blocks of each 2-hr session. (All four half-hour blocks were used because the conclusions did not change when the first half-hour block of each session was eliminated.) Table 2 indicates that the data were generally stable; the standard error of the mean for the number of left and right responses was less than 10% of the mean in 117 of 168 cases. Those cases in which the standard error of the mean was greater than 10% of the mean were more likely to occur in the first 2-hr session.

Analyses were based on obtained amounts and on the programmed delays because the subjects frequently started to turn the knob in Experiment 1 during the delay period (i.e., before the reinforcer access period), and therefore the programmed and obtained delays were usually identical. In all cases the significance level for all statistical analyses was set at p = .05.

Proportion of Responses for Reinforcers

Figure 2 presents the proportion of responses for larger reinforcers, less delayed reinforcers, and larger, more delayed reinforcers for each subject in Experiments 1 and 2. The proportions are means of the pairs of corresponding conditions (i.e., conditions that were identical except that the contingencies for rod pushes to the left and to the right were reversed). For example, the proportion of responses for a given subject for larger reinforcers is the mean of the proportions for Conditions 2 and 4. Averaging the data across corresponding conditions served to attenuate any position bias that may have been present.

Choice proportions obtained in Experiments 1 and 2 were compared with indifference using t tests. These tests indicated that in Experiment 1 all of the choice proportions were significantly higher than indifference [larger reinforcers: $t(5) = 10.6$, $M = 0.77$, $SE = 0.3$; less delayed reinforcers: $t(5) = 4.23$, $M = 0.67$, $SE = 0.4$; larger, more delayed reinforcers: $t(5) = 4.43$, $M = 0.73$, $SE = 0.4$]. In Experiment 2, no choice proportion differed significantly from .50 [larger reinforcers: $t(5) = 1.29$, $M = 0.60$, $SE = 0.5$; less delayed reinforcers: $t(5) = 1.69$, $M = 0.58$, $SE = 0.5$; larger, more delayed reinforcers: $t(5) = 1.66$, $M = 0.49$, $SE = 0.01$].

Statistical tests comparing the proportions in Experiments 1 and 2 indicated that the subjects in Experiment 1 responded significantly more for larger reinforcers than did the subjects in Experiment 2, $t(10) = 2.83$. The proportions of responses for less delayed reinforcers were not significantly different, $t(10) = 1.50$. The proportions of responses for larger, more delayed reinforcers in Experiment 1 were

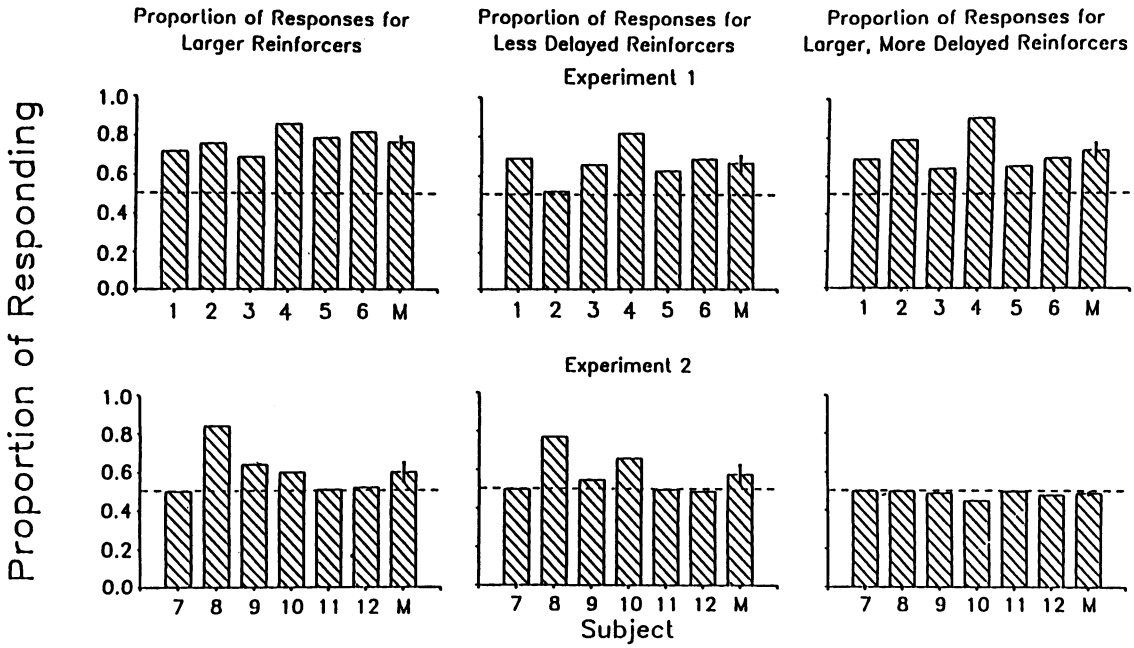

Fig. 2. Proportion of responses for larger reinforcers, less delayed reinforcers, and larger more delayed reinforcers in Experiment 1 (top panels) and Experiment 2 (bottom panels). The dashed horizontal lines indicate indifference (i.e., a response proportion of .5). The bars are the standard errors of the means.

significantly larger than the same proportions in Experiment 2, $t(10) = 6.0$.

DISCUSSION

Results of these experiments indicate that humans' sensitivity to variation in reinforcer amount was not similar across different methods of delivery. Several findings support this conclusion. First, in Experiment 2 the proportions of responses for larger reinforcers were not significantly different from indifference, but the corresponding proportions in Experiment 1 were significantly higher than indifference, as has generally been the case in previous research (e.g., King & Logue, 1987; Logue et al., 1986). Second, the proportions of responses for larger reinforcers in Experiment 1 were significantly higher than the corresponding proportions in Experiment 2. Third, in Experiment 2 the proportions of responses for larger, more delayed reinforcers were not significantly different from indifference, but the corresponding proportions in Experiment 1 were significantly higher than indifference. Fourth, the proportions of responses for larger, more delayed reinforcers in Experiment 1 were significantly higher than the corresponding proportions in Experiment 2. Together, all of these results suggest that the subjects in Experiment 2 were less sensitive to variation in reinforcer amount than were the subjects in Experiment 1.

The present results are consistent with the simple schedule research that indicates that simple schedule sensitivity varies as a function of the procedures used to obtain the reinforcers (e.g., Buskist et al., 1988; Holland, 1958; Long et al., 1958; Matthews et al., 1977). For example, Matthews et al. found that simple VI schedule sensitivity was exhibited only when a consummatory response was present. The results from the present experiments are also consistent with research involving nonhuman subjects indicating that the absence of a second, consummatory, response decreases subjects' sensitivity to the contingencies of reinforcement (Hawkins & Pliskoff, 1964; Iglauer & Woods, 1974; Llewellyn et al., 1976).

It is possible that sensitivity to reinforcer amount, and perhaps sensitivity to the contingencies of reinforcement in general, is deter-

Table 2

Mean number of responses and reinforcers for each subject and condition in Experiments 1 and 2, the amount earned per reinforcement in Experiment 1, and the number of points delivered per reinforcement for Experiment 2. Numbers in parentheses are the *SEM*.

		Responses		Reinforcers		Amount per reinforcer[a]	
Subject	Condition	Left	Right	Left	Right	Left	Right
				Experiment 1			
1	1	685.3 (100.5)	364.5 (46.4)	54.8 (4.0)	42.5 (4.6)	3.2 (0.4)	4.2 (0.7)
	2	780.8 (46.4)	311.3 (18.9)	59.5 (2.7)	36.0 (2.4)	7.0 (0.1)	2.3 (0.1)
	3	363.3 (17.1)	700.3 (16.1)	41.5 (0.5)	58.8 (1.1)	3.4 (0.1)	3.6 (0.1)
	4	317.8 (15.5)	851.5 (27.2)	35.0 (1.1)	58.3 (0.3)	2.5 (0)	7.7 (0)
	5	842.0 (8.8)	318.0 (19.7)	58.8 (0.9)	39.0 (0.4)	3.8 (0)	3.6 (0.1)
	6	1,120.5 (18.2)	558.3 (13.5)	59.3 (1.1)	38.0 (0.4)	8.0 (0.1)	2.3 (0.0)
	7	259.0 (19.3)	646.5 (19.1)	27.0 (1.4)	58.5 (1.3)	2.4 (0.1)	7.4 (0.1)
2	1	327.5 (35.9)	233.3 (18.4)	51.5 (1.5)	37.8 (2.1)	1.4 (0.1)	1.4 (0.1)
	2	467.8 (46.1)	218.3 (32.0)	56.3 (2.3)	30.3 (2.2)	3.8 (0.1)	1.3 (0)
	3	291.8 (34.5)	227.3 (32.0)	46.8 (2.1)	34.3 (3.4)	3.4 (0.1)	3.6 (0.1)
	4	199.3 (16.2)	680.0 (56.5)	27.0 (1.1)	57.3 (1.3)	1.4 (0)	4.3 (0.1)
	5	527.0 (58.1)	334.5 (49.0)	49.5 (5.1)	36.5 (3.9)	2.2 (0)	2.1 (0)
	6	1,185.3 (29.5)	390.5 (35.7)	57.3 (0.6)	39.0 (2.7)	4.5 (0.1)	1.3 (0)
	7	137.5 (27.4)	685.3 (32.9)	16.8 (1.7)	55.8 (1.4)	1.3 (0)	4.3 (0.1)
3	1	240.8 (20.8)	252.0 (15.7)	49.0 (2.5)	50.3 (2.8)	2.1 (0.1)	2.1 (0)
	2	453.0 (35.2)	185.8 (27.9)	58.5 (1.0)	21.5 (2.9)	4.4 (0.1)	1.4 (0.1)
	3	161.8 (27.3)	480.5 (72.9)	25.5 (7.5)	57.3 (1.3)	2.0 (0.2)	2.1 (0.1)
	4	240.8 (10.3)	472.0 (7.7)	14.0 (1.5)	58.8 (0.8)	1.2 (0.1)	4.5 (0)
	5	231.3 (5.2)	233.8 (15.0)	44.8 (2.2)	43.8 (3.0)	2.1 (0.1)	2.1 (0.1)
	6	748.5 (30.7)	286.3 (40.6)	58.8 (1.1)	22.8 (3.4)	4.6 (0)	1.2 (0.1)
	7	269.3 (20.8)	343.3 (17.8)	44.8 (1.0)	58.8 (1.9)	1.0 (0.1)	4.3 (0.1)
4	1	323.5 (156.4)	283.3 (139.0)	29.3 (11.7)	26.0 (10.3)	2.3 (0)	2.3 (0.1)
	2	1,069.8 (61.4)	151.3 (25.3)	58.3 (0.8)	17.8 (2.4)	4.4 (0.1)	1.4 (0)
	3	263.0 (13.4)	1,096.0 (115.6)	33.8 (2.3)	56.8 (1.3)	2.4 (0.1)	2.5 (0.1)
	4	160.0 (9.4)	1,397.0 (37.5)	19.5 (0.9)	57.8 (2.1)	1.7 (0)	5.2 (0)

Table 2 (*Continued*)

Subject	Condition	Responses		Reinforcers		Amount per reinforcer[a]	
		Left	Right	Left	Right	Left	Right
	5	1,119.5 (72.9)	217.3 (26.9)	57.5 (0.5)	25.8 (1.0)	2.7 (0.1)	2.6 (0)
	6	1,631.8 (102.6)	169.5 (32.4)	59.3 (0.8)	24.5 (3.2)	5.3 (0)	1.5 (0.1)
	7	91.8 (11.0)	844.3 (87.1)	12.3 (0.9)	51.8 (1.5)	1.5 (0)	4.7 (0.1)
5	1	489.8 (102.1)	549.3 (100.8)	52.3 (0.5)	52.8 (1.1)	2.0 (0.04)	2.0 (0.04)
	2	748.0 (103.3)	237.0 (24.5)	58.8 (0.9)	33.8 (1.3)	4.5 (0.08)	1.5 (0.02)
	3	241.5 (14.5)	436.5 (20.6)	44.3 (0.9)	57.8 (0.8)	2.3 (0.03)	2.4 (0.04)
	4	189.5 (15.2)	844.0 (23.0)	35.0 (2.0)	58.8 (0.5)	1.6 (0.02)	4.9 (0.05)
	5	390.0 (22.9)	235.0 (11.8)	58.0 (0.7)	43.8 (1.2)	2.3 (0.03)	2.2 (0.05)
	6	606.8 (24.6)	295.3 (16.4)	58.5 (0.7)	58.5 (1.8)	4.5 (0.06)	1.5 (0.03)
	7	228.0 (48.0)	364.0 (36.8)	35.3 (7.8)	53.8 (3.5)	1.5 (0.01)	4.2 (0.07)
6	1	127.3 (13.1)	100.5 (6.5)	50.3 (2.8)	33.3 (6.8)	2.2 (0.05)	2.3 (0.04)
	2	256.5 (2.6)	62.3 (2.5)	57.8 (0.8)	18.0 (3.0)	4.7 (0.02)	1.5 (0.01)
	3	83.5 (2.4)	207.0 (12.0)	28.8 (0.6)	58.5 (1.5)	2.3 (0.03)	2.4 (0.03)
	4	60.3 (4.6)	320.5 (24.9)	22.0 (3.1)	58.0 (0.7)	1.5 (0.01)	4.7 (0.07)
	5	324.3 (12.4)	170.3 (6.5)	58.0 (1.7)	42.0 (2.6)	2.3 (0.03)	2.1 (0.11)
	6	397.8 (17.4)	247.8 (25.0)	58.3 (0.8)	54.3 (2.3)	5.0 (0.04)	1.4 (0.03)
	7	97.0 (7.9)	306.0 (8.4)	18.8 (1.0)	55.0 (0.9)	1.4 (0.02)	4.7 (0.10)
				Experiment 2			
7	1	717.8 (45.9)	676.8 (20.3)	58.3 (0.8)	58.3 (0.6)	22.0 (0.0)	22.1 (0.1)
	2	771.5 (54.6)	829.3 (14.6)	58.3 (1.1)	58.3 (0.9)	33.0 (0.0)	11.0 (0.0)
	3	868.5 (16.2)	918.0 (22.9)	58.3 (1.0)	58.3 (0.5)	22.0 (0.0)	22.1 (0.1)
	4	926.8 (30.4)	978.5 (28.0)	58.3 (1.4)	58.0 (0.8)	11.0 (0.0)	33.1 (0.1)
	5	964.8 (45.1)	998.5 (33.8)	58.3 (0.6)	58.8 (1.7)	22.0 (0.0)	22.0 (0.0)
	6	750.0 (21.9)	815.5 (41.5)	58.0 (0.6)	58.8 (1.1)	33.1 (0.1)	11.0 (0.0)
	7	881.3 (32.4)	948.0 (24.3)	58.3 (0.5)	58.0 (1.5)	11.0 (0.0)	33.0 (0.0)
8	1	340.5 (91.4)	268.8 (62.2)	58.0 (1.1)	55.3 (1.7)	22.0 (0.0)	22.0 (0.0)

Table 2 (*Continued*)

Subject	Condition	Responses		Reinforcers		Amount per reinforcer[a]	
		Left	Right	Left	Right	Left	Right
	2	516.5 (64.4)	77.5 (15.2)	58.3 (0.3)	19.5 (3.9)	33.0 (0.0)	11.0 (0.0)
	3	135.8 (5.5)	465.3 (16.5)	38.3 (1.4)	59.0 (0.4)	22.0 (0.0)	22.0 (0.0)
	4	116.3 (11.6)	517.3 (55.5)	31.0 (2.7)	59.3 (0.5)	11.0 (0.0)	33.0 (0.0)
	5	495.0 (14.1)	156.3 (7.2)	59.0 (0.4)	39.5 (0.9)	22.0 (0.0)	22.1 (0.1)
	6	271.8 (9.5)	293.8 (13.3)	57.0 (1.5)	57.8 (0.9)	33.1 (0.2)	11.0 (0.0)
	7	236.5 (9.5)	271.3 (2.5)	55.8 (2.5)	57.0 (1.2)	11.0 (0.0)	33.0 (0.0)
9	1	600.0 (68.7)	638.0 (72.7)	57.8 (1.1)	57.5 (1.7)	22.0 (0.0)	22.0 (0.0)
	2	1,287.8 (110.6)	451.5 (78.7)	58.5 (1.0)	42.3 (4.3)	33.0 (0.0)	11.0 (0.0)
	3	719.8 (12.9)	947.5 (15.6)	57.8 (0.9)	59.0 (0.4)	22.0 (0.0)	22.0 (0.0)
	4	812.3 (42.5)	842.0 (147.7)	58.0 (0.8)	58.5 (1.0)	11.0 (0.0)	33.1 (0.0)
	5	792.0 (59.1)	710.5 (45.7)	58.3 (0.9)	58.0 (0.6)	22.0 (0.0)	22.0 (0.0)
	6	655.3 (39.5)	705.8 (46.6)	57.0 (1.1)	58.0 (1.1)	33.1 (0.1)	11.0 (0.0)
	7	734.0 (67.3)	699.3 (50.9)	58.0 (0.6)	58.8 (1.3)	11.0 (0.0)	33.0 (0.0)
10	1	141.5 (3.6)	121.0 (5.3)	56.8 (2.7)	45.5 (4.7)	22.0 (0.0)	22.0 (0.0)
	2	171.3 (14.4)	122.8 (8.8)	58.3 (3.0)	48.8 (1.7)	33.1 (0.2)	11.0 (0.0)
	3	123.0 (4.9)	197.5 (3.9)	50.0 (1.5)	58.3 (1.8)	21.9 (0.1)	22.0 (0.0)
	4	153.0 (8.8)	252.8 (12.3)	51.0 (2.2)	58.0 (0.4)	11.0 (0.0)	33.1 (0.1)
	5	297.8 (12.1)	129.5 (4.1)	59.0 (1.2)	42.3 (1.7)	22.1 (0.1)	22.0 (0.0)
	6	181.3 (21.1)	243.5 (24.6)	50.8 (1.3)	58.0 (1.2)	33.1 (0.2)	11.0 (0.0)
	7	288.3 (15.9)	257.5 (8.7)	58.0 (0.7)	53.0 (1.1)	11.0 (0.0)	33.1 (0.1)
11	1	538.0 (43.0)	644.8 (24.6)	55.5 (2.2)	55.8 (2.8)	22.0 (0)	22.0 (0.02)
	2	677.5 (40.6)	681.0 (31.3)	59.3 (2.1)	57.8 (1.3)	33.2 (0.2)	11.0 (0.02)
	3	629.8 (28.8)	652.5 (46.1)	57.0 (1.9)	57.5 (1.0)	22.0 (0.02)	22.0 (0.07)
	4	475.5 (11.7)	517.5 (8.5)	53.0 (1.6)	57.5 (0.9)	11.0 (0.02)	33.0 (0)
	5	576.8 (17.9)	609.0 (22.7)	57.3 (1.8)	58.0 (1.6)	22.0 (0)	21.9 (0.18)
	6	575.3 (16.6)	592.3 (15.1)	56.0 (1.2)	56.3 (0.8)	33.2 (0.1)	11.0 (0)

Table 2 (*Continued*)

Subject	Condition	Responses		Reinforcers		Amount per reinforcer[a]	
		Left	Right	Left	Right	Left	Right
	7	557.3 (38.6)	571.0 (34.4)	54.0 (1.4)	56.3 (1.0)	11.0 (0.02)	33.0 (0)
12	1	558.5 (90.8)	515.3 (89.4)	54.8 (9.9)	50.5 (4.8)	22.1 (0.13)	22.0 (0)
	2	817.3 (25.7)	755.0 (29.0)	57.5 (0.7)	59.0 (1.2)	33.0 (0.20)	11.0 (0)
	3	957.8 (22.0)	954.8 (58.9)	58.3 (1.1)	58.8 (1.6)	22.0 (0.06)	22.0 (0)
	4	860.8 (41.1)	931.5 (11.3)	57.8 (0.8)	58.8 (1.6)	11.0 (0.01)	33.1 (0.11)
	5	904.8 (18.3)	980.5 (29.5)	57.8 (1.1)	57.5 (0.7)	22.0 (0.04)	22.1 (0.06)
	6	873.5 (24.7)	927.8 (16.8)	57.8 (0.8)	58.5 (1.4)	33.0 (0.05)	11.0 (0)
	7	995.5 (22.9)	926.0 (34.9)	59.0 (1.5)	58.3 (1.0)	11.0 (0.00)	33.1 (0.05)

[a] The amounts for Experiment 1 are the cents per point, and for Experiment 2 the amounts are the number of points delivered per reinforcer.

mined by multiple overlapping sources of feedback, and that this effect is present across species. Different degrees of information about reinforcer amount may be available in different experiments. With the method of Logue and associates discussed in the introduction, reinforcer amount is signaled by (a) the presence (duration) of the stimulus signaling the reinforcer access period (e.g., the light above the knob), (b) proprioceptive feedback from the knob turns, and (c) the cumulative number of points displayed on the respective counters, which will vary with the duration of the reinforcer access period and preference for a response alternative. In Experiment 1 reinforcer amount was signaled by all three of these types of feedback, and also by (d) the stimuli posted above each alternative indicating the exchange rates (monetary value) of the points. In Experiment 2, reinforcer amount was indicated only by (a) the number of points delivered per reinforcement and (b) the rate of point delivery during a given reinforcement (because the duration of point deliveries was 6.6 s for all conditions).

The above analysis indicates that the presence or absence of a consummatory response results in different degrees of feedback regarding reinforcer amount. Elimination of the consummatory response eliminates some of this feedback (e.g., the motor feedback) and appears to decrease sensitivity to reinforcer amount. Therefore, it seems that human subjects' sensitivity to the contingencies of reinforcement (e.g., reinforcer amount) varies as a function of the degree of feedback. If this is so, manipulation of the degree of feedback should result in systematic changes in subjects' sensitivity to the contingencies. Further, it should be possible to determine how different sources of feedback combine to produce sensitivity to the contingencies of reinforcement and to determine the relative importance of different sources of feedback.

The present analysis may also explain the differing results between the study by Matthews et al. (1977) and the studies by McDowell and Wood (1985) and Buskist et al. (1988), all of which were described in the introduction. In the Matthews et al. experiment, without the consummatory response, the contingencies of reinforcement were signaled by the number of points displayed on the counter (as in Experiment 2). However, in the McDowell and Wood experiment, the contingencies (e.g., reinforcer amount) were signaled by the number of points on the counter and by stimuli (cards) indicating the exchange rates for the points. Therefore, in the McDowell and Wood experiment there was an additional

source of (salient) feedback that was not present in the Matthews et al. experiment. In the Buskist et al. experiment, reinforcer amount was correlated with response rate and was indicated both cumulatively ("total session points earned") and by amount per reinforcement ("points earned this time"). Changes in reinforcer amount as a function of responding were indicated explicitly under the heading of "points earned this time"; therefore, there was a distinct discriminative stimulus indicating changes in reinforcer amount as a function of responding. These additional sources of feedback may have produced the subjects' sensitivity to the contingencies that was absent in the Matthews et al. experiment. Therefore, the present analysis predicts that removal of the posted exchange values in the McDowell and Wood (1985) study and the "points earned this time" heading in the Buskist et al. (1988) study would result in decreased sensitivity, or insensitivity, to the scheduled contingencies in those experiments.

The subjects in Experiment 2 exhibited significantly less self-control than did the subjects in Experiment 1. Note that the subjects in Experiment 2 did not demonstrate impulsiveness (i.e., they did not prefer the smaller, less delayed alternative). They were indifferent between larger and smaller reinforcers and between less and more delayed reinforcers, and therefore they were indifferent between larger, more delayed and smaller, less delayed reinforcers. This is significantly different from the behavior of the subjects in Experiment 1, who demonstrated sensitivity to variation in both reinforcer amount and delay, thereby demonstrating self-control. Self-control and impulsiveness are determined by sensitivity to variation in both reinforcer amount and reinforcer delay. Decreases in the degree of self-control can therefore be produced by (a) decreasing sensitivity to variation in reinforcer amount or (b) increasing sensitivity to variation in reinforcer delay. The reduction in self-control found in Experiment 2 is consistent with this interpretation in that choice was significantly less sensitive to variation in reinforcer amount in Experiment 2 than it was in Experiment 1.

In the present experiments, there was no postreinforcement delay. The preference for the less delayed reinforcers exhibited by the subjects in Experiment 1 may have resulted from a preference for a higher obtained rate of reinforcement, as the subjects could obtain the less delayed reinforcers more quickly than the more delayed reinforcers (i.e., reinforcer delay and obtained rate of reinforcement were confounded). This possibility is unlikely because, if this were the case, then the subjects in Experiment 2, as well as the subjects in Experiment 1, should have preferred the less delayed reinforcers (the reinforcer delays were identical in the two experiments). Although the addition of a postreinforcement delay would have equated the total time needed to obtain a reinforcer from the left and right response alternatives, this would not necessarily have eliminated covariation between reinforcer delay and obtained overall rate of reinforcement (number of reinforcers divided by session time). Concurrent independent VI schedules were used in the present experiments. If a detention period had been used, and the subjects still preferred the less delayed reinforcers over the whole session, they still would have obtained more of the less delayed reinforcers than the more delayed reinforcers. Therefore, the problem would still have been present. Given independent schedules of reinforcement, it is not possible to control the overall obtained reinforcement rates. Any preference for one alternative over another will result in unequal overall obtained reinforcement rates, regardless of the source of the preference. The most common method of controlling obtained reinforcer frequency is to use equal, dependent concurrent schedules of reinforcement. However, if such schedules are used and the subjects are maximizing (and there is evidence that humans maximize in self-control paradigms, e.g., King & Logue, 1987; Logue et al., 1986), then the optimal strategy is to allocate behavior equally between the two alternatives, irrespective of the reinforcer amounts and delays (pigeons' behavior tends in this direction also, e.g., Chavarro & Logue, 1988). In other words, to maximize reinforcement on dependent concurrent schedules, subjects should be insensitive to variations in reinforcer amount and delay. Under such conditions the study of human self-control and sensitivity to variation in reinforcer amount and delay becomes meaningless.

In summary, the present experiments found that the method of delivering reinforcer amount can have a significant effect on subjects' sensitivity to variation in reinforcer amount. Hu-

mans' sensitivity to reinforcer amount may vary as a function of the degree of feedback that the subjects receive concerning the consequences of responding.

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